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APPLICATIONS OF SCIENCE TO WARFARE IN FRANCE

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THE chemists say this is the chemists' war, the engineers claim it as theirs, while a distinguished French physicist calls the struggle "a grandiose physical phenomenon," and the medical and surgical fraternity demonstrate their prevention from epidemics and rendering possible the return to the front some three fourths or more of all invalided and wounded has made the continuance of trench warfare possible.

Verdun has been named "the metallurgical battle" and also "the battle of the trucks," referring in the first case to the importance of the iron ore deposits of the Briey region located a few miles to the northeast and in the second to the vast numbers of automobile trucks employed by the French on the only highway open at the outbreak of the battle, namely, that connecting Bar-le-Duc with Verdun.

The meteorologist is listened to with attention by the Great Headquarters, as was the astrologer of yore, before an extensive offensive is undertaken; and the geologist is consulted for information as to where to halt and dig in, where shelters may be safely built and as to the probability of underground waters. Even the astronomer's services are considered of great importance, for example, in the preparation of new artillery tables and maps, the improvement and invention of instruments, which differ but slightly in principle, however much they may differ in the nature of their use, from those with which he is familiar. Again, the statistician is a most valuable person when an offensive is being planned. Also the mathematician France, at least, has found indispensable, for in the person of M. Painlevé he sits at the head of them all as minister of war, whose civil, technical staff is largely made up of eminent members of the same profession. Is this then a mathematicians' war?

In truth, chemistry, physics, hygiene, mathematics, engineering, geography and geodesy, metallurgy, geology, bacteriology, meteorology, or pretty much the whole curriculum of physical and natural sciences, and their applications, are each of them fundamentally essential in modern warfare, some of course more apparently so than others, but almost none could be spared and the war carried on successfully.

Two most important corollaries immediately suggest themselves:

First, the war can not be successfully prosecuted if there is lacking any of the necessary raw materials including chemical, physical and metallurgical supplies such as nitrates, optical glass, coal and steel, to name but a few. The operations of modern warfare are so complex and interrelated that the want of crucial supplies in one domain may seriously hamper all; hence the phenomenon of which there are instances innumerable, of intensive scientific research in the development of substitutes as one or another essential material becomes scarce. There is many an interesting memoir in this field awaiting the end of the struggle to see the light.

Second, modern warfare can be waged successfully only by the proper organization of these diverse scientific elements in addition to, and coordinated with or incorporated in, the military establishments.

In a completely mobilized country, such as France, it is essential that each man in the community, which is nearly identical with the military establishment, be assigned to the task for which he is best fitted—or there must be scientific organization and management to secure the country's greatest possible efficiency.

What is this organization? how and to what extent are the sciences used in warfare? and how are the scientific men mobilized or otherwise made use of? The complete answers to such questions can not be expected in so short a space.

It was the writer's privilege to be one of a scientific mission sent abroad by the National Research Council, immediately after America's entry into the war, for the purpose, among others, of finding answers to the above questions. A brief statement of some of the impressions gained during a three months stay in England and France may not be without interest. Our mission had extraordinary if not unique opportunities for close observation of all the aspects of science in warfare, not only from many interviews, visits to laboratories, manufacturing plants, and technical ministerial bureaus, but also from inspection at the fronts of the French and British armies of the organization, application and actual operation of the scientific and technical services, all of which were shown and explained to the most minute detail.

The most striking impression brought home is one of unity of purpose, perfect adaptation and coordination of the several branches, a harmonious whole, in fact, made up of separate and often highly intricate parts constituting an organization in which all the sciences and their applications blend into one, which is focused by the admirably trained technical and staff officers on the sole object of destroying the enemy. The French traits of individuality, initiative, and self-reliance are, however, in no sense lessened or dulled by this cooperation.

What are some of the component parts of this unity in scientific warfare? We shall mention but a few in illustration of the whole. Let us first consider examples of the applications of physics to warfare, some of which owe much of their efficacy to the relative immobility of the front.

Of all the branches of this science the one that had in recent years been lagging behind the others and to whose development the least attention was being paid, was acoustics; yet it is not an exaggeration to say that the application of the principles of acoustics, or sound, is of the greatest importance at the front.

One of the most highly developed is the location of enemy guns, concerning the details of which a volume could be written; suffice it to say that in the French armies there are several systems in use, all of which will locate to within a few yards an enemy battery at ten or twenty kilometers, indicate the caliber of the guns, differentiate between the sounds of discharge, flight through the air and bursting, and record each and every separate shot; and the spot from which the shot was fired may, under certain conditions, be located before the shell bursts. There have been developed several ingenious listening devices built on entirely different acoustical principles for use in mine warfare, by means of which enemy mining operations may be exactly located. Again for the location of sounds in the air, especially useful, for example, in locating airplanes at night, several new types of sound apparatus of extreme sensitiveness are in use. For submarine detection, some of the most promising methods for further improvement are based on the use of still other sound detecting devices. Wonderfully powerful megaphones for use in battle have also been developed.

Acoustics as an active branch of physics has most decidedly come into its own.

What about optics? One would expect this branch to show perhaps the highest developments and most interesting applications. Relative to acoustics, however, optics takes second rank as to new developments, although there are to its credit many beautiful modifications and improvements and not a few entirely new instruments, and the output of optical instruments is enormous. Optical signalling or observation, however, is not depended upon alone in battle, although several types are in use.

In photography and the technique of photographic map making there have been great improvements, brought about directly by military necessity, especially in aerial photography, apparatus and interpretation. One of our most interesting visits at the front was to the photographic headquarters of a French army corps, where we listened to an admirably delivered, illustrated lecture on the taking and interpretation of aerial photographs. There are at the front schools for training balloon observers, who have to reconstruct maps from their perspective photographs; certain of the aviators are similarly trained, although the making of maps from the photos they take is mainly the work of a special branch of the service. The art of map making from photographs, as carried out at the front, is practically a new branch requiring great skill, and is evidently of the first importance, as oftentimes the success of an offensive is largely dependent upon the quality of this work. These special services for which there are schools, are recruited from the army by competitive examinations, thus automatically obtaining the personnel best adapted.

As would be expected there have been not a few advances made in applications of electricity, especially wireless apparatus and methods, signalling and listening devices. There may be, for example, during a battle more than 1,500 separate wireless stations sending messages simultaneously; provision is successfully made for preventing interference and sorting out this great mass of signals so as to avoid confusion. Portable wireless outfits are supplied by the tens of thousand—requiring for the construction of these instruments alone a veritable army of skilled mechanics.

The reading public is, perhaps, more familiar with some of the applications of chemistry to warfare, such as the asphyxiating, tear-producing and other noxious gases used in waves or clouds and lately more and more in shells; and the importance of nitric acid, toluol and the like has been impressed on every one. The stupendous scale on which such substances must be produced to keep up with the demands of the armies is perhaps not sufficiently realized, nor is there any adequate appreciation of the amount of scientific investigation being carried out. In France I understand there are some twenty-five distinct laboratories engaged in nitrogen fixation research alone.

Turning now to meteorology, what has the weather man to do with war? He too plays a capital rôle. With his sounding balloons he keeps the troops informed as to when a gas attack may be expected and when it would be profitable to start one; the artillery depend on him for data to calculate important corrections, as for wind, humidity, pressure, and temperature and upper air conditions in sighting their guns; the aviators as to prevailing winds, especially high up, and for general weather conditions; the balloon men keep in close touch with him, and even the transport service depends upon him for advance information as to muddy roads; headquarters relies upon him for knowledge of impending fog or rain and other changes—the weather man has a very heavy responsibility in helping to decide the most propitious moment for an attack on a grand scale, and if his forecast is erroneous, disaster may result. There is a special meteorological service—in fact there are two in addition to the regular service of peace times—attached to the French armies and linked to the British. The personnel, as in all the French services, is of the highest order of ability, being recruited largely from the professions and trades which depend upon the weather.

One of the most impressive sights we were permitted to witness at the French front was the firing of a battery of 320 mm. (13 inch) cannon, mounted on railway trucks, at an invisible target 19.5 kilometers distant. It took four shots to accomplish the end sought, which was demolishing an enemy battery that had been located the day before by "sound ranging" and photography.

What does such an operation mean in preparation and execution, viewed as a scientific experiment?

In the first place it presupposes an exact knowledge of the region expressed in accurate maps, including of course territory in possession of the enemy—the preparation of these maps is one of the most elaborate of the technical geographic services of the army; this service is usually supplemented when possible by triangulation from fixed observatories, and photographic mapping from airplanes or balloons; it assumes, further, that the cannon of the battery have, as we might say, been calibrated, that is the characteristics of their firing determined by shooting at a recognized and exactly located object of about the same range and making a known angle with the target; the relative positions of battery and target and their exact distance apart should also be known. A big gun is displaced somewhat with every shot fired and is brought back to position by reference to a fixed base by means of a series of optical measurements. Some of the allowances and corrections that have to be made in firing are: variations in weight of projectiles—showing the need of uniformity, homogeneity and geometrical exactness in their manufacture, not a simple matter; weight, quality, age and temperature of the firing charge—which gives but a hint as to a most elaborate series of researches in the physical chemistry of ballistics; the age, state of erosion and temperature of the gun—another series of unsolved problems; the numerous atmospheric corrections such as direction and force of the wind at the various levels of the trajectory, the temperature, pressure, and humidity of the air, all of which produce disturbances that vary with the distance of the target or what is the same, muzzle velocity of the shot as well as the shape of the shell.

There have been prepared elaborate tables containing these corrections and others which are constantly being improved by further research; the theory of probabilities is also made use of in an elaborate way for each caliber to control the inevitable dispersion of the shots after all known corrections are made. With all these data, how does the artillery officer know the accuracy of his fire at a target invisible to him and 20 kilometers away? If he has the local mastery of the air use is made of airplanes which signal the location of each shot, otherwise he must depend on stationary balloons, special observatories or even on his calculations alone if the weather be bad.

Finally, it is not necessary merely for the shot to strike the target, it must explode at the right instant and have a suitable "fragmentation"—here is opportunity for more research in mechanics, chemistry, and metallurgy. It may be stated in passing, the French were compelled to develop a modified cast-iron or semi-steel shell, as they could not obtain enough steel for shells the first year of the war. It is not necessary to state that they succeeded in this.

Such in brief is the mechanism of artillery fire, for the accomplishment of which many of the sciences collaborate, and for the rendering it more exact there is still room for considerable research in astronomy, geodesy, metallurgy, chemistry, physics, and meteorology. The battery we visited demolished the 20-kilometer-distant target at the fourth round, as was shown from photographs taken before and after firing—nothing is left to chance.

Turning to aviation, we need not dwell upon the wonderful advances that have been made in design of planes and motors, all of which has been dependent largely upon scientific investigation of the highest order, and numerous and varied are the research establishments, both governmental and private, for their execution. Here again one is impressed by the magnitude and grandiose scale on which this highly intricate and beautiful branch of the service has been developed. The scientific instruments alone with which the avions are equipped, say five types to a machine on the average, meant the development of an important technical industry in the products of which improvements are made almost daily.

We have not touched upon the applications of science in the various branches of military engineering, some of which are new in this war, requiring the highest directing, technical talent and thousands of workmen; the advances in medicine, sanitation and surgery have not been treated, nor have we mentioned trench warfare with its manifold engines, appliances and materials, necessitating the creation of new industries accompanied in all cases by elaborate scientific research. Gas warfare alone is based on what is literally a stupendous industry requiring the employment of chemists and other scientifically trained men on a great scale. Again there are large and very active laboratories maintained for the examination of enemy munitions and appliances of all kinds, and for the development of new and improved types.

A matter of vital importance is maintaining the quality and standards of the munitions supply, and this is done only by constant vigilance of the inspection and designing forces among which are many specialists of the highest grade and the total number engaged in this work amounts to many thousands. There is nothing so disastrous to the morale of the troops in battle as premature shell explosions. The quality of the steel must be beyond reproach. Here, as elsewhere, the United States will do well to profit from the European experience. The methods of steel casting as ordinarily practised in America are not considered abroad as entirely satisfactory for the production of "sound steel" from which shells, and especially high explosive shells, should be made. I had opportunities to visit several British and French steel works and shell plants, and my observations confirm this belief, namely, that speaking broadly, the European steel-ingot casting practise is superior to ours, and I may add they consider theirs none too good.

For utilizing to best advantage the many suggestions and inventions that are proposed, there have been established, in Great Britain and France, inventions bureaus, to which are attached men of eminence in science and engineering. The most promising ideas are tried out under competent direction, and in some cases the board itself initiates and executes investigations of great military interest. Applications for patents may be held in abeyance and kept secret on the advice of this board.

A word now as to the organization of the scientific and technical services. Both the British and French, early in the war, saw the advantages to be gained by separating the fighting from the supply departments, hence the creation in each country of a ministry of munitions. It might almost be said that the able-bodied inhabitants of France belong to either the war or munitions ministry; or in other words the population is organized for war. The fundamental principle involved in this organization is that each shall do that for which he is best fitted in the national work of destroying the enemy. This principle admitted, the solution for any particular individual is a relatively simple matter; it is necessary of course for the administrative heads and military chiefs to exercise good judgment in the balancing of the organism as between military and industrial service.

Men most competent to give advice, such as the members of the Academy of Sciences, are asked for advice and they sit, as individuals or as representing the Academy, in an advisory capacity on many important committees. Men who have an aptitude for research are put to work in one or another of almost innumerable laboratories on problems of military importance.

Examples enough have been given to impress upon the reader, I hope, the tremendous magnitude, enormous scope and far-reaching extent of the problem of modern warfare looked at from the point of view of the applications of science and the employment of scientific and technical men.

The wonderful French organization was not all built up in a day, neither were mistakes avoided nor could all the developments that have taken place been foreseen. In the early days of the war men were sent to the front whose brains to-day would be an invaluable asset; national laboratories were almost depopulated; the military authorities were indifferent to advice from civilian specialists. To-day one would be embarrassed to decide whether an officer in one of the specialized services was an officer before the war or, let us say, a professor of chemistry. The national laboratories have been multiplied ten-fold; and such care is now taken to protect productive brains that it may happen that the inventor of a new device is not allowed to go to the front to try it out.

In conclusion, I am tempted to quote the scientific definition of this war as given by a distinguished Belgian officer in the French service. The early incursions of the Germans were for the visible supplies of potential energy above ground—the cereals; the present war is their attempt to gain control of the sources of invisible potential energy below ground—coal and iron; and the next may be caused by their thirst for the sources of kinetic energy—the waterfalls.